

Probing the Galaxy with Superbubbles 3D Simulations

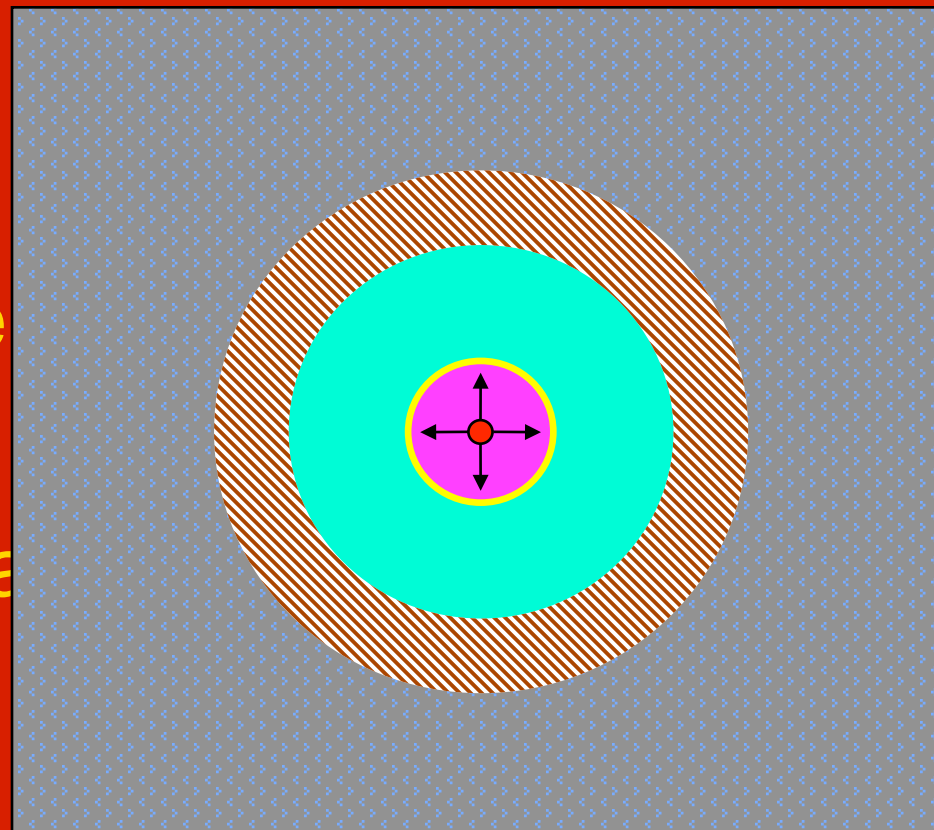
Nicole Wityk
University of Calgary

Outline

- Analytic Models
- Our Simulations
 - Setup
 - Hydrodynamic Simulations
 - Magnetohydrodynamic Simulations
- Bubbles as Probes
 - Axial ratios
 - Fitting Kompaneets to Magnetized bubbles
 - Faraday Rotation

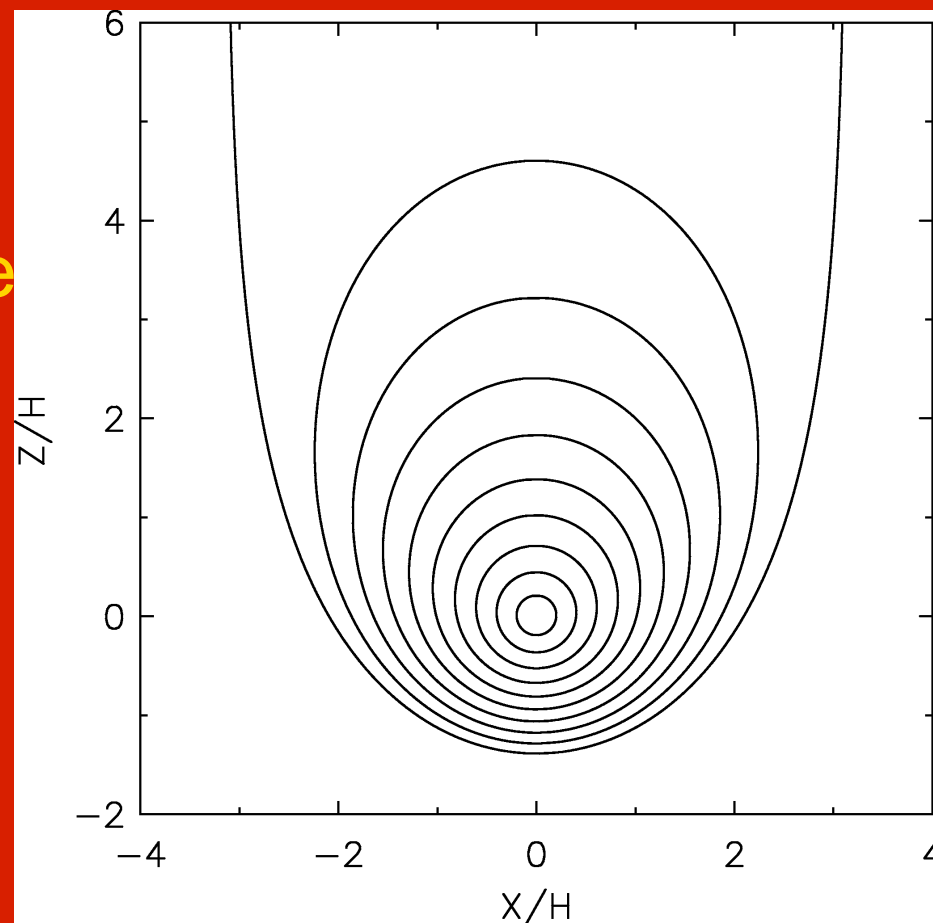
Analytic Model: Castor

- Analytic solution
- Assumption:
Constant Atmosphere
- Spherical evolution
- Solves for the radius as
a function of time



Analytic Model Kompaneets

- Analytic Solution
- Assumption
Exponential Atmosphere
- Evolution
 - Early Stages
 - Radius \ll Scale Height
 - Spherical
 - Late Stages
 - Radius $>$ Scale Height
 - Elongated



Our Simulations

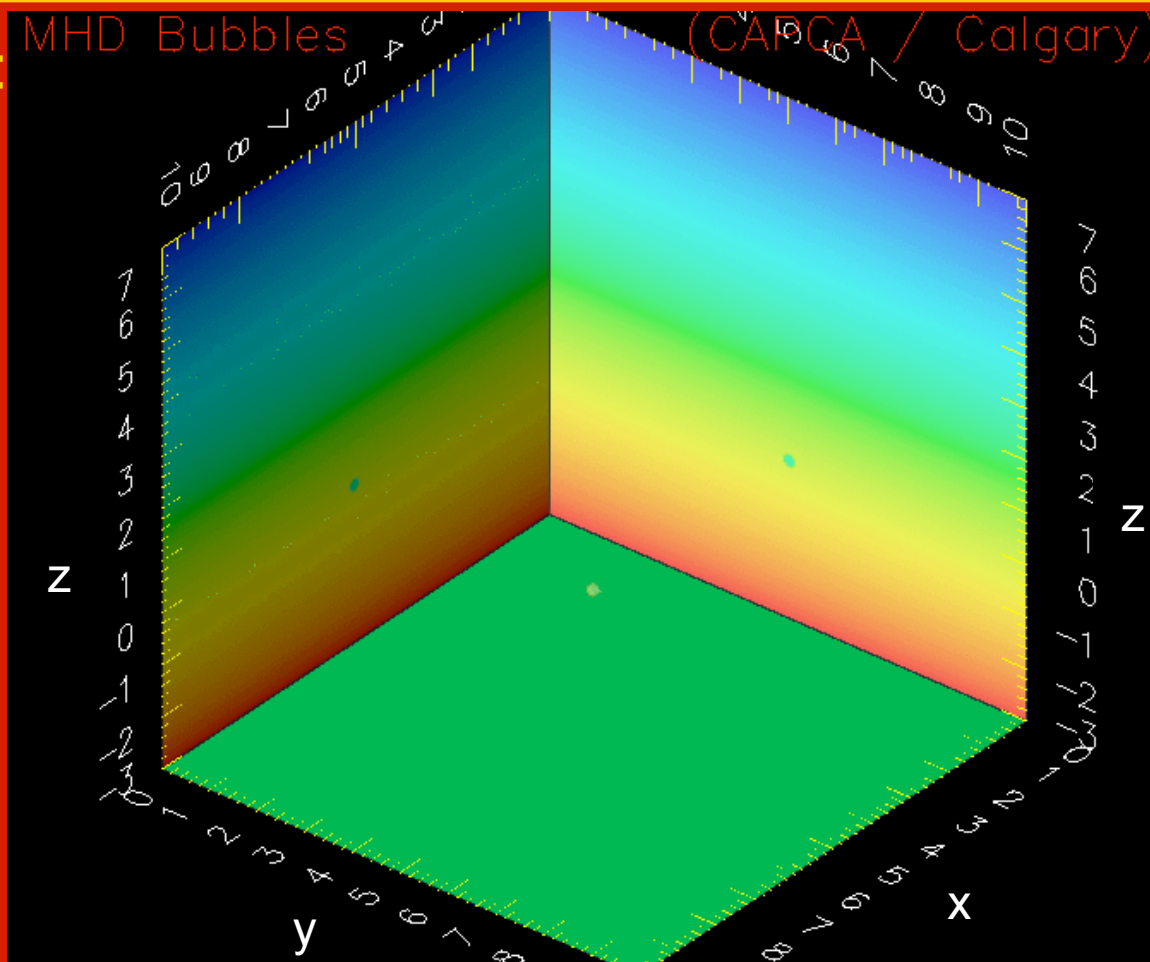
- Fully 3D Numerical Simulations
 - ZEUSMP MHD code (Heyes et al. 2006)
- Adiabatic evolution in an initially isothermal atmosphere
- HD and MHD simulations
- Determine the effects of magnetic fields on bubble morphology
 - Effect of fitting analytic hydrodynamic solutions to magnetized bubbles on values derived from those fits

Our Simulations Setup

- Two ISM density distributions in isothermal medium:
 - Exponential
 - Dickey & Lockman (1990)
- Two magnetic field geometries:
 - $B = \text{constant}$
 - $B \sim \rho^{1/2}$ (equipartition)
- Magnetic field strength
 - $\beta = P_{\text{gas}} / P_{\text{mag}}$
- Resolution: 200 x 200 x 200 (5 pc pixels)

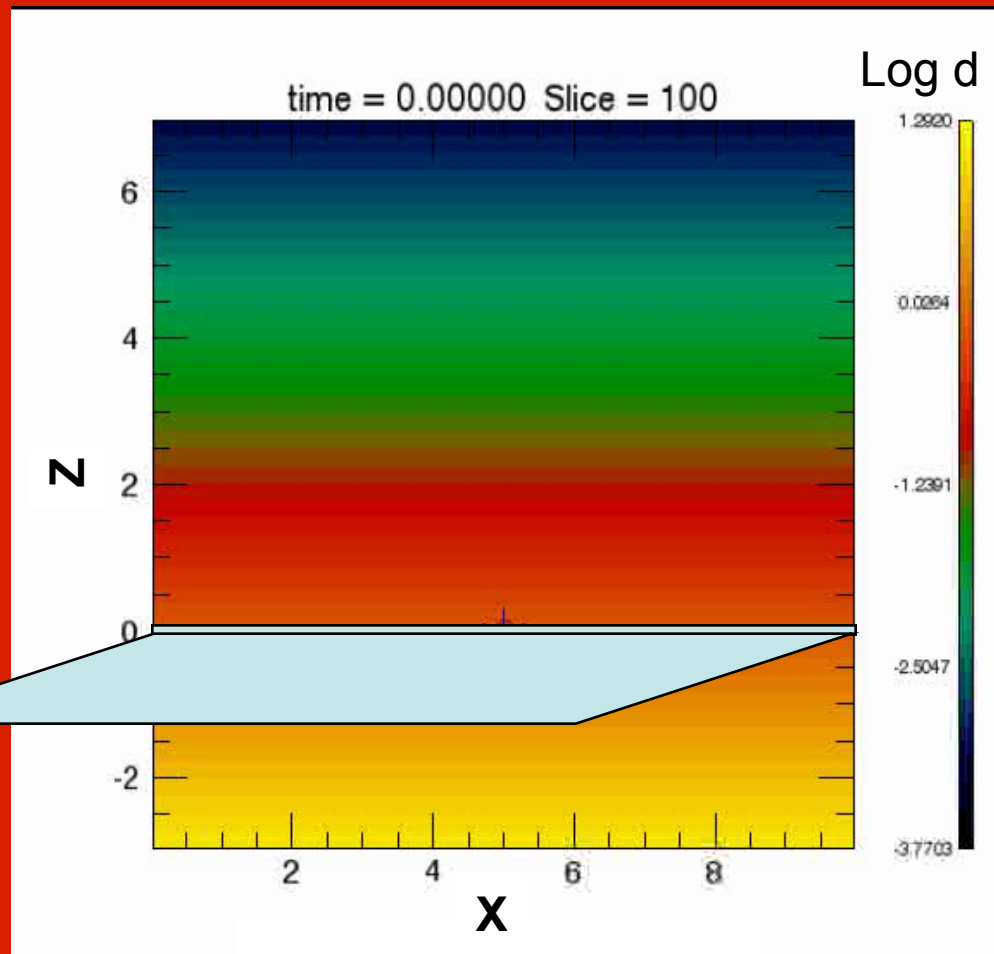
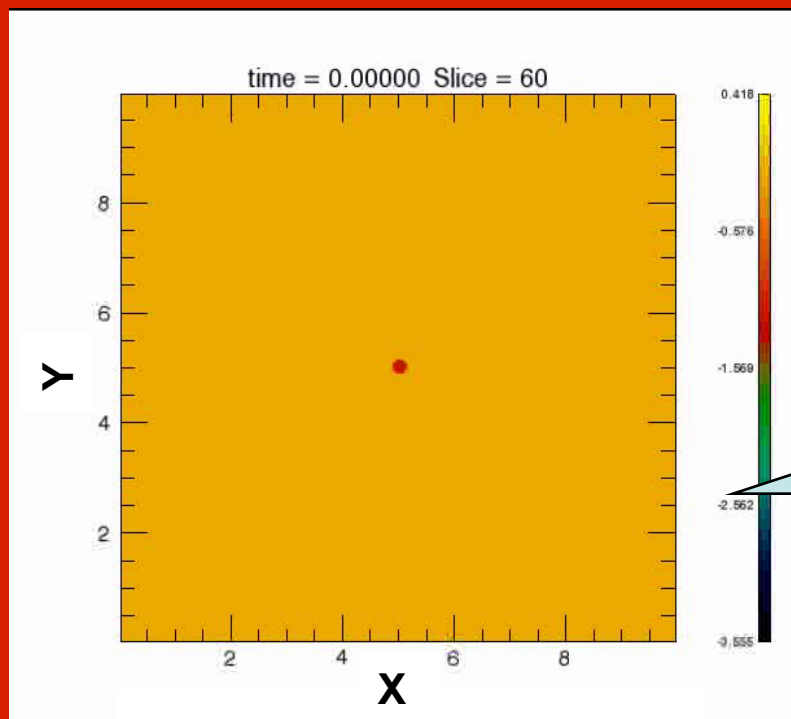
Simulation Hydrodynamic

- Mechanical Luminosity:
 $L_{M,Source} = 3 \times 10^{37} \text{ erg/s}$
- Atmosphere:
Exponential
- Magnetic Field:
None



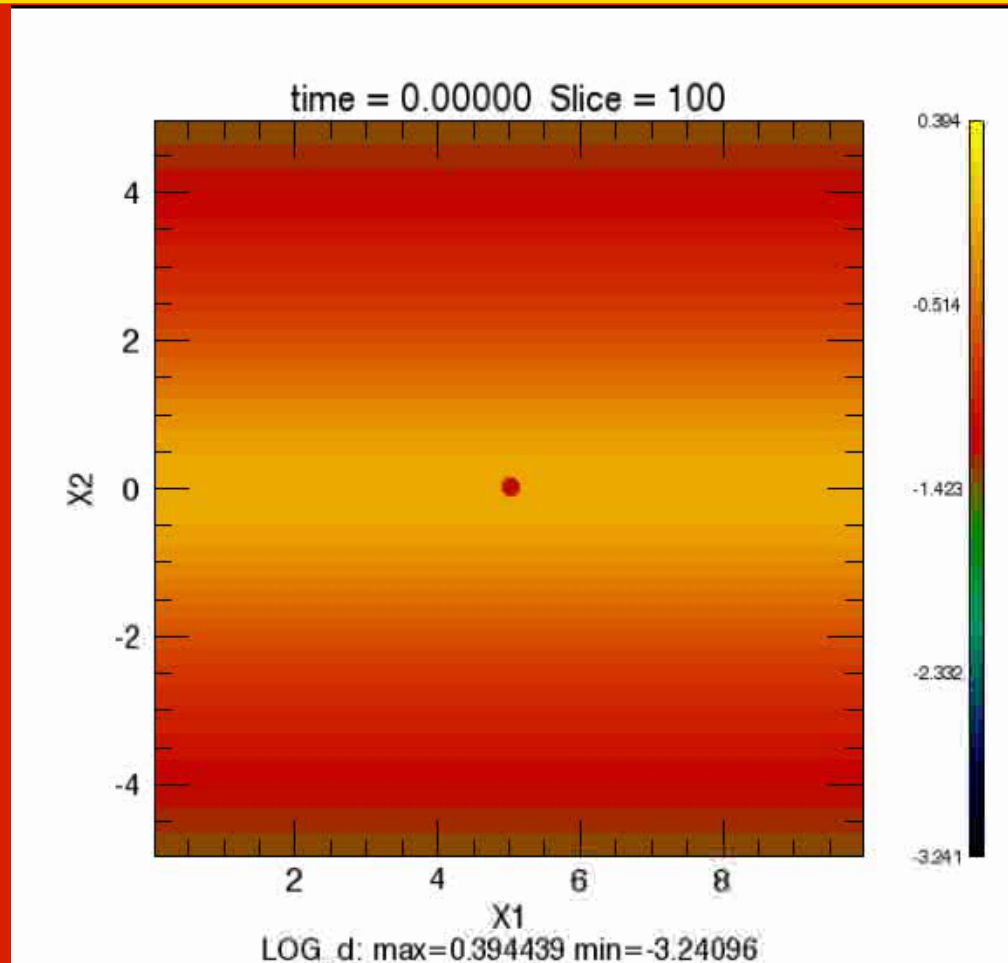
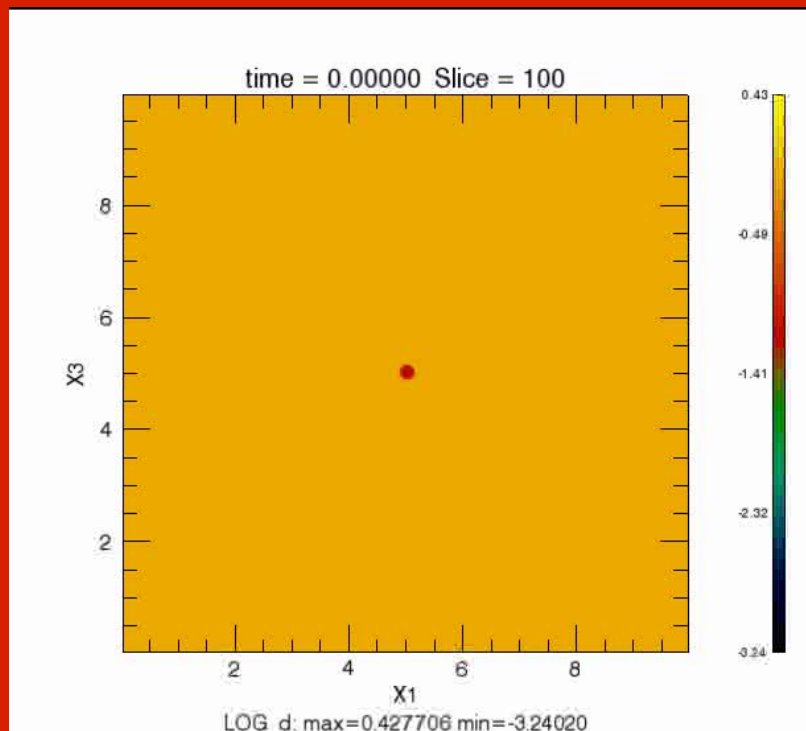
Simulation Hydrodynamic

- $L_{M,source} = 3 \times 10^{37}$ erg/s
- Atmosphere:
Exponential



Simulation Hydrodynamic

- $L_{M,source} = 3 \times 10^{37}$ erg/s
- Atmosphere:
Dickey & Lockman



Simulation

Magnetohydrodynamic

- Mechanical Luminosity:

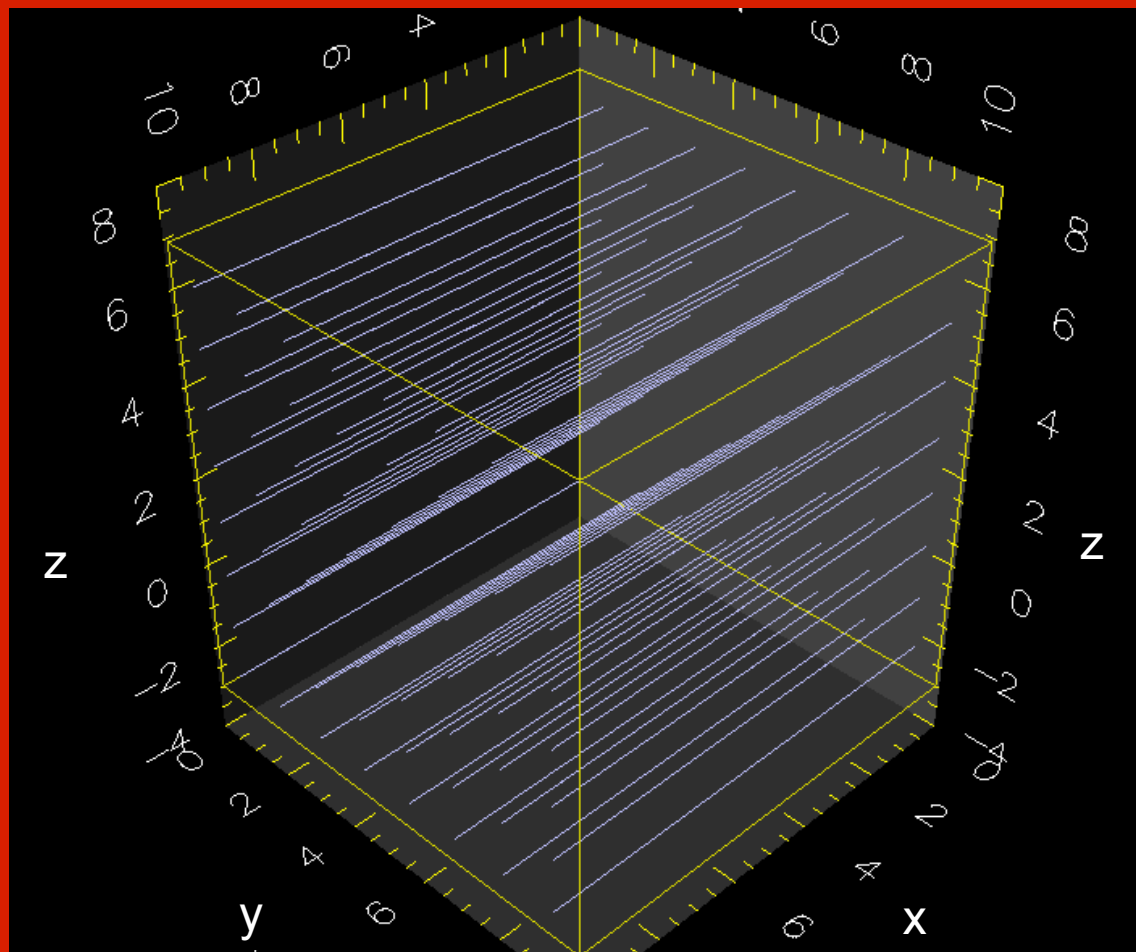
$$L_{M,Source} = 3 \times 10^{37} \text{ erg/s}$$

- Atmosphere:

Exponential

- Magnetic Field:

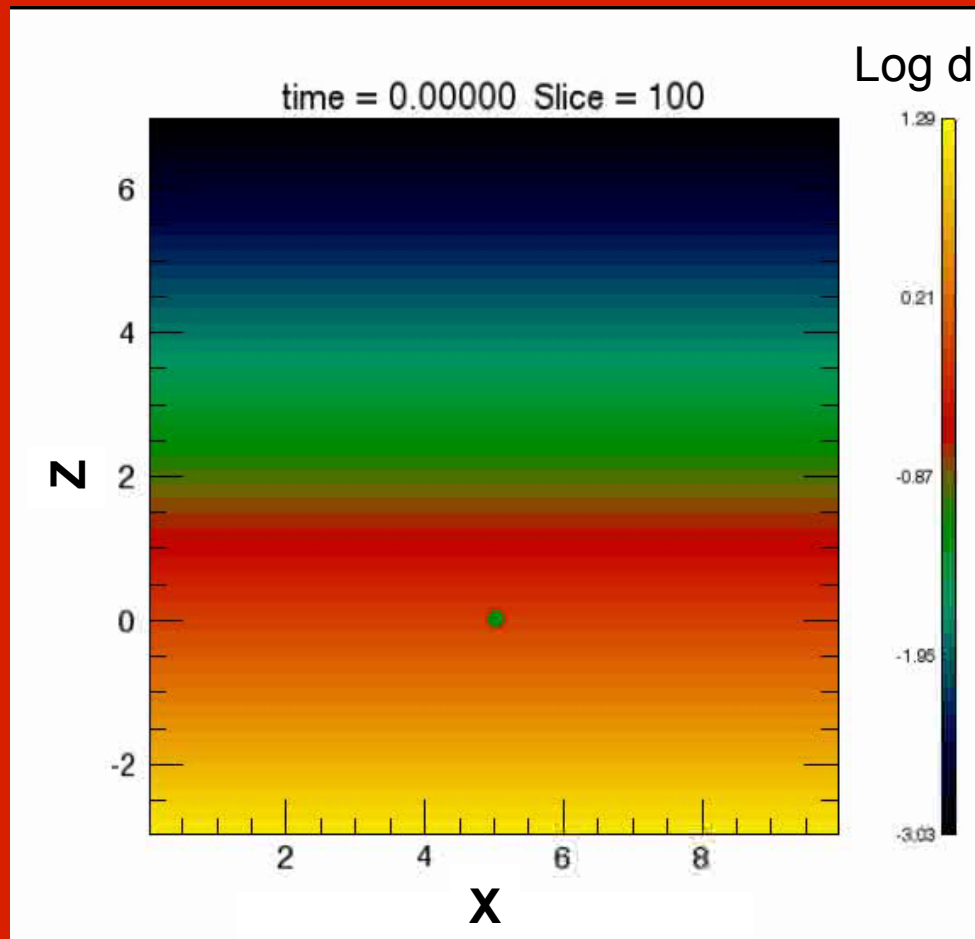
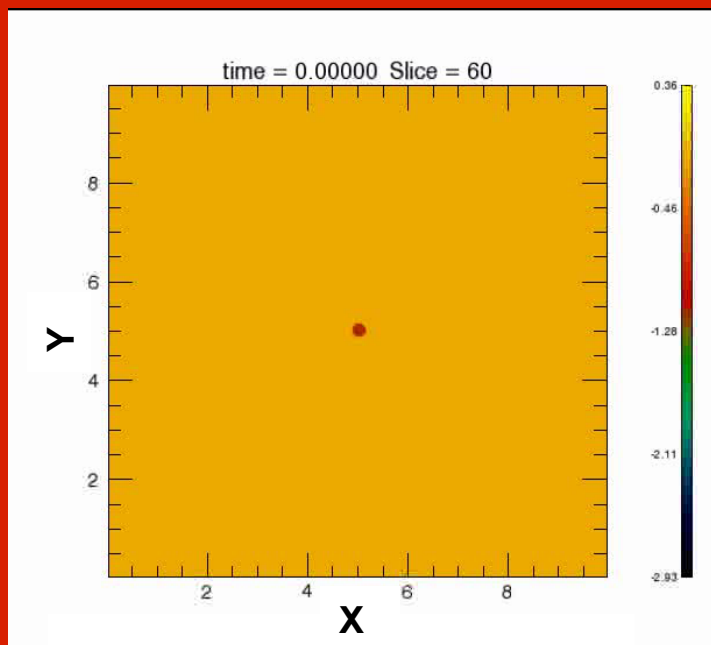
Constant B , $\beta = 1$



Simulation

Magnetohydrodynamic

- $L_{M,source} = 3 \times 10^{37}$ erg/s
- Atmosphere:
Exponential
- Constant B, $\beta = 1$

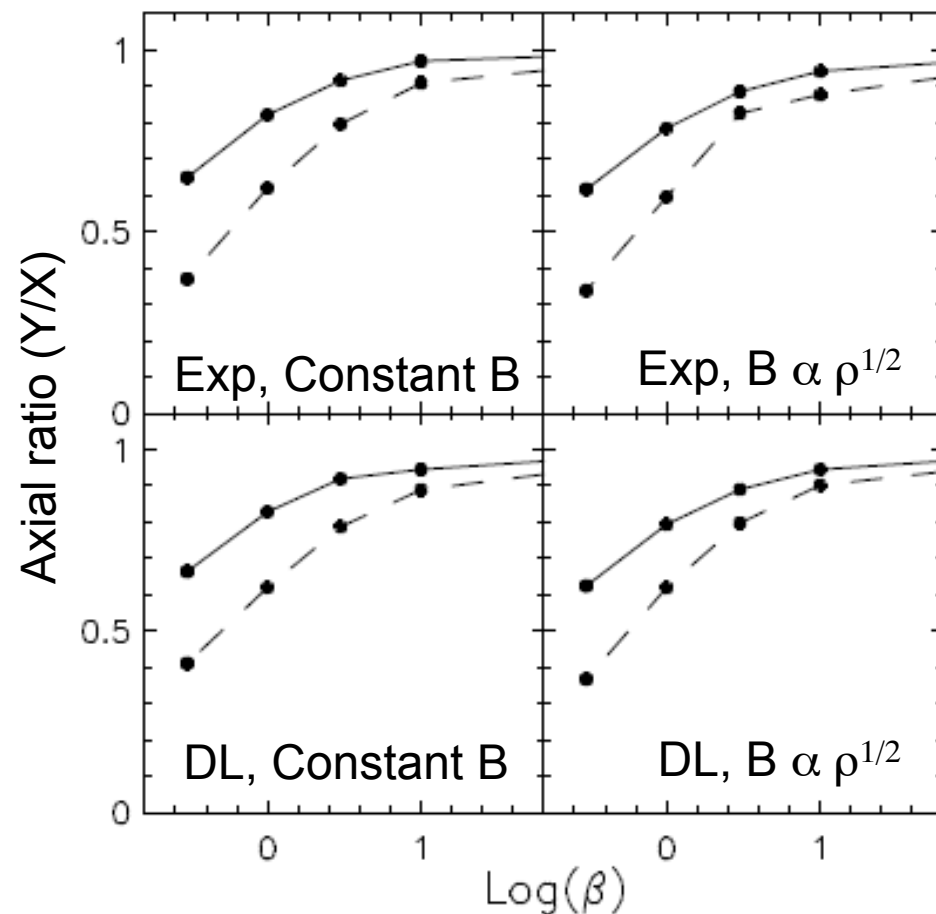
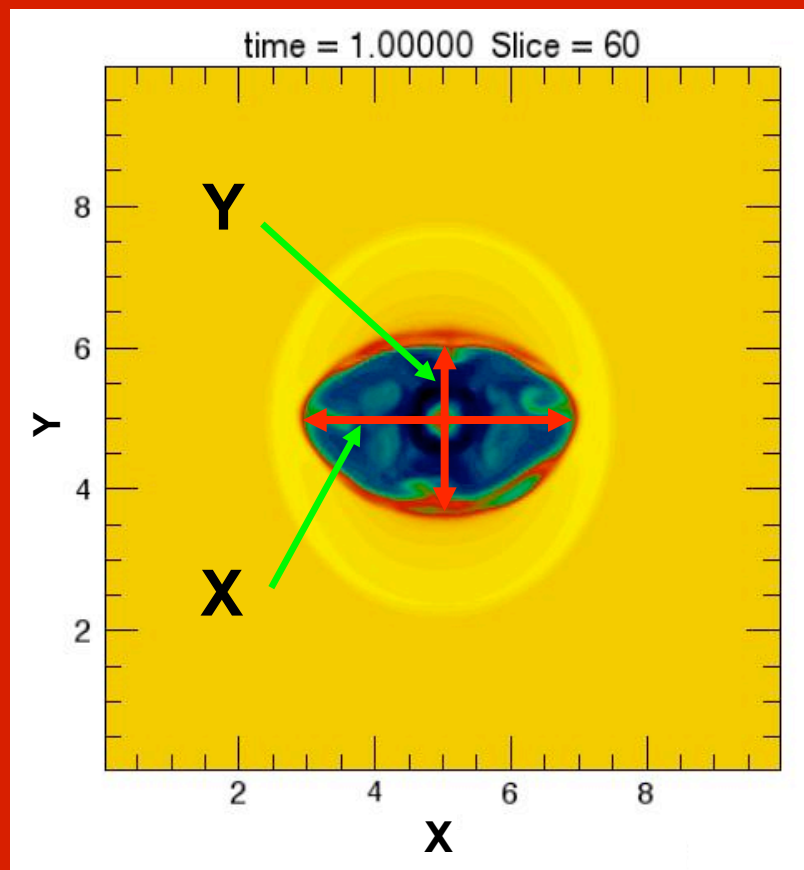


Bubbles as Probes

- Axial Ratios
- Fitting Kompaneets Solution with continuous injection (Basu et al. 1999) to Magnetized Bubbles
- Faraday Rotation

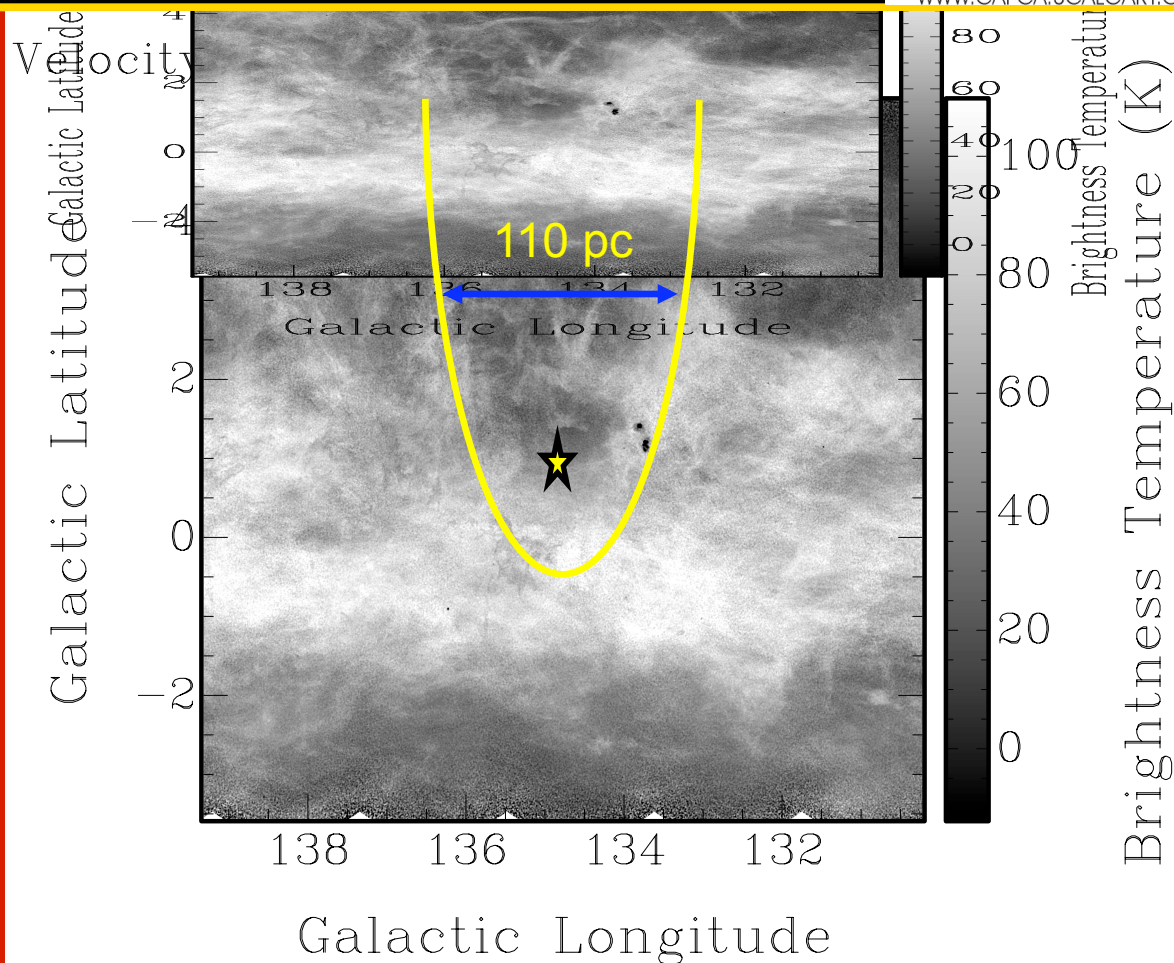
Axial Ratios Y/X

Y/X Axial ratios at level of



Fitting Kompaneets to Magnetized Bubbles

- W4 Chimney
- Located in Perseus arm
- 2.35 kpc away
- Source: OCl 352
(l,b = 134°.7,0°.9)
- 110 pc across at
b = 3°.5





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Fitting Kompaneets to Magnetized Bubbles



WWW.CAPCA.UCALGARY.CA

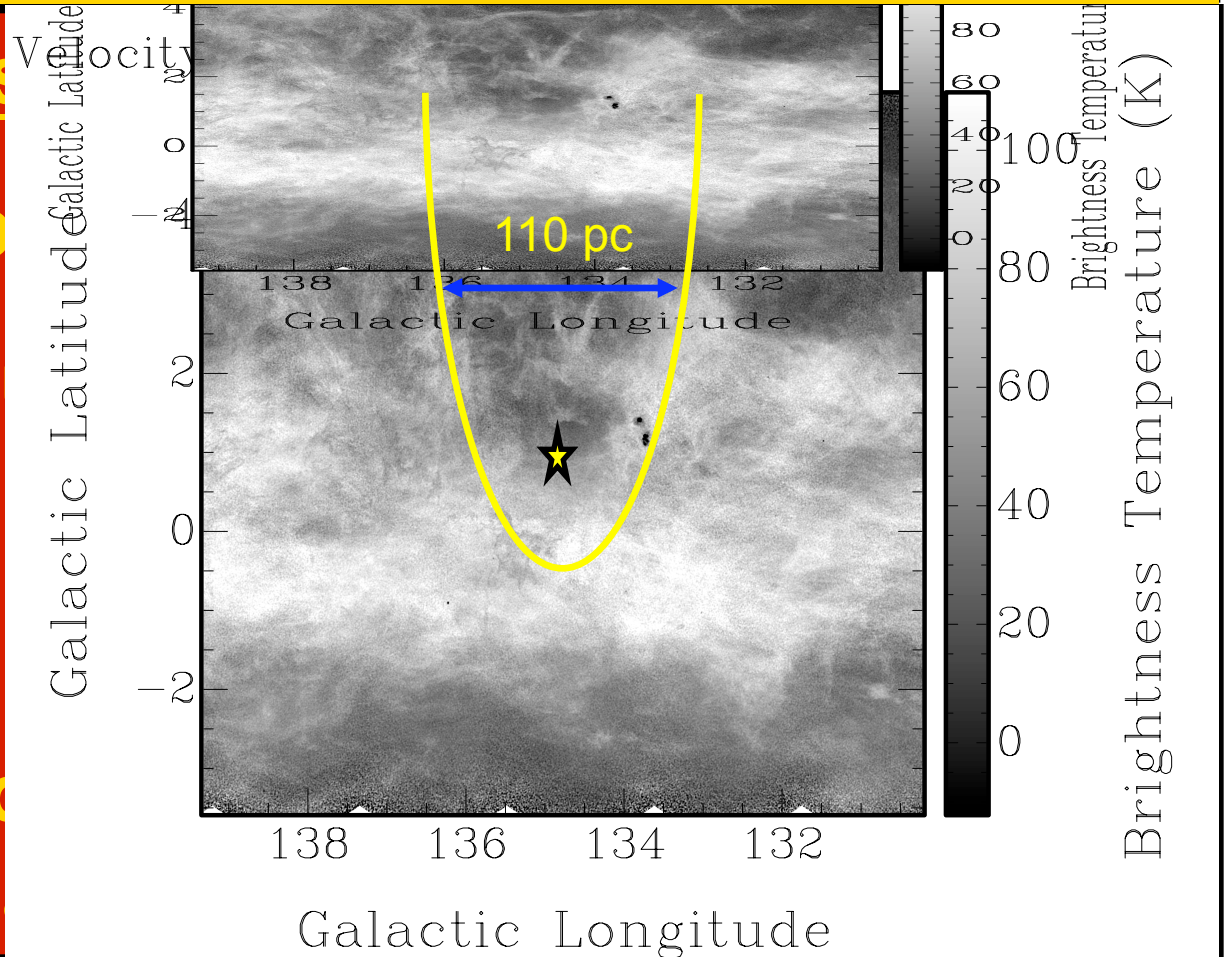
Basu et al 1999 **Pos**

Fitted Kompaneets
W4 may be
Solution to W4

Kompaneets sol

- Age: 2.5 Myr **field**
- Scaleheight:
25pc

**What effect do
model to a m**



derived values?

Fitting Kompaneets to Magnetized Bubbles

Simulation Data

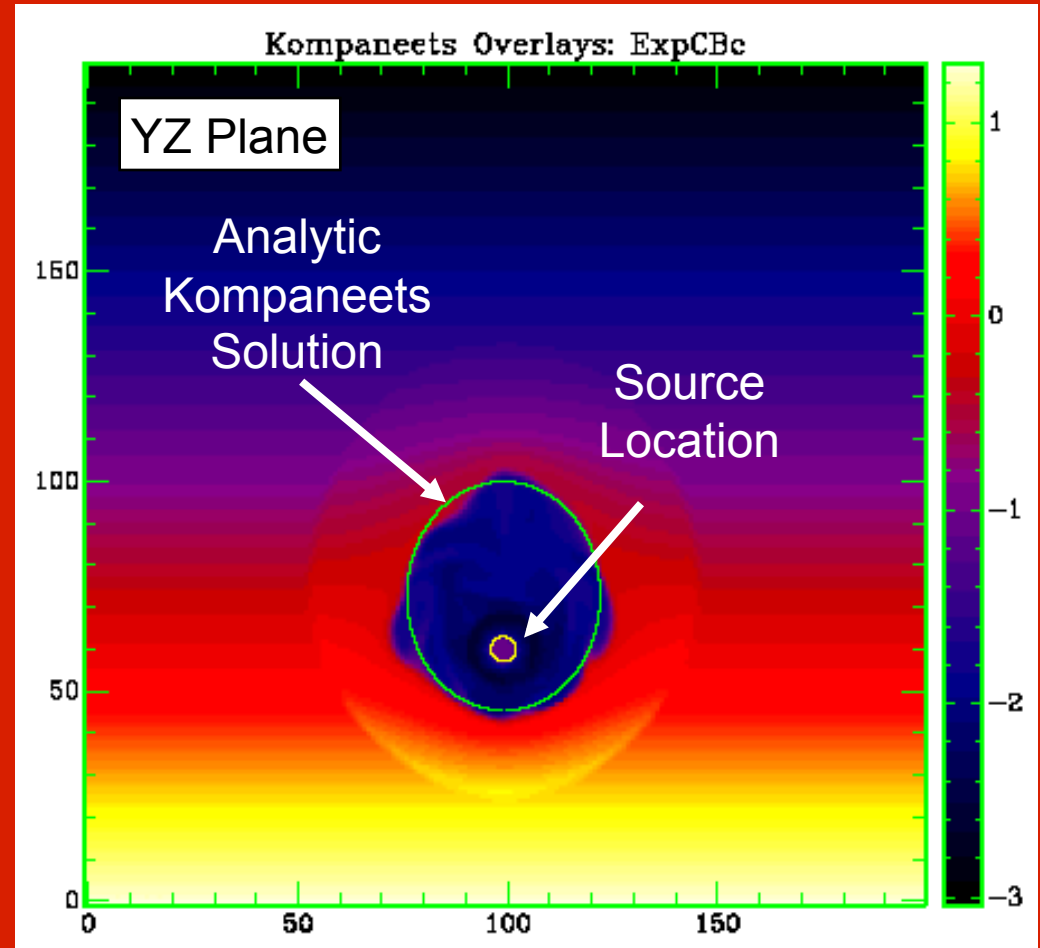
- Overlays fit to $H = 100$ pc
- Age = 7.3 Myr

Green Overlay

- bubbles give lower values for $H = 60$ pc
- Age = 2.79 Myr

White Overlay

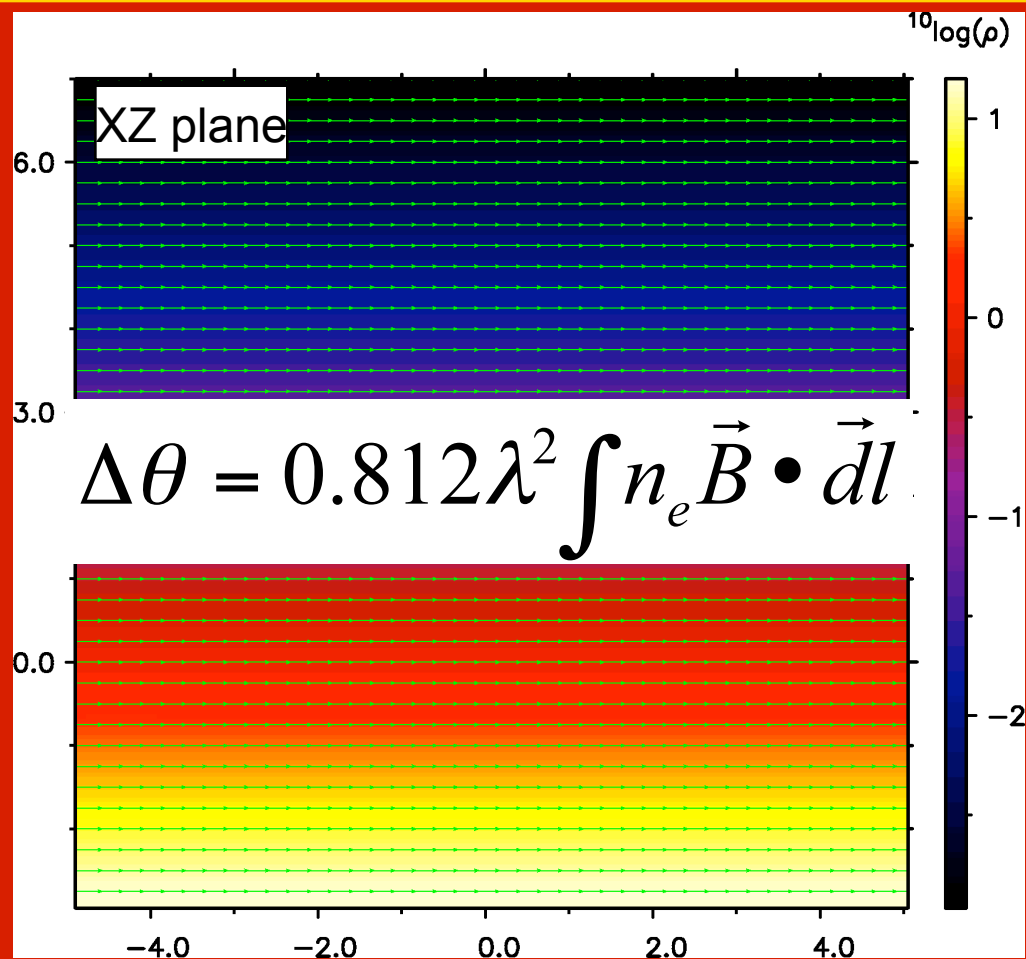
- scale height by 30-50% and for $H = 110$ pc
- age by 50%
- Age = 3.78 Myr



Effect of Magnetic Field

MHD Simulation

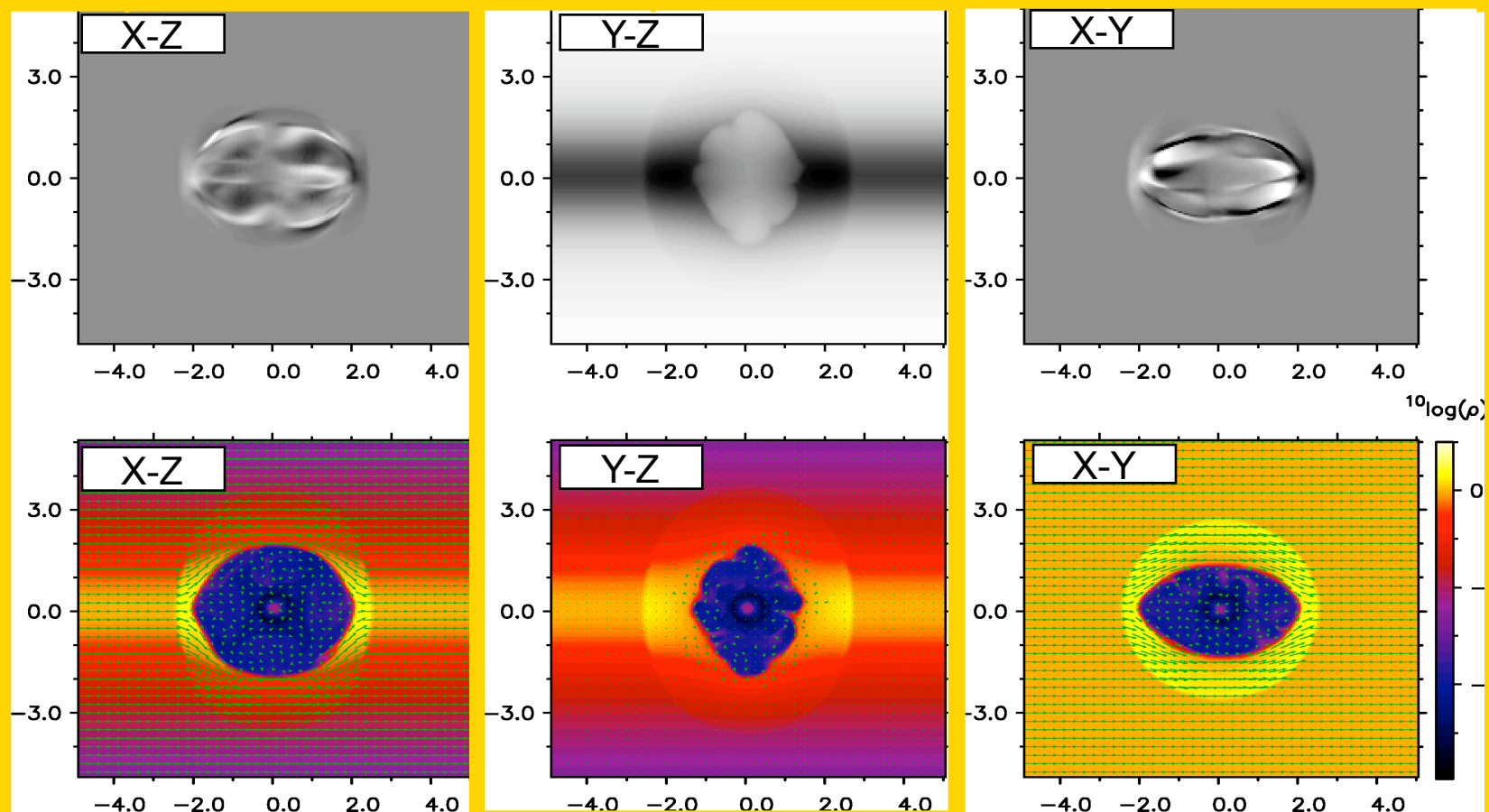
- Green arrows: direction and strength of B field projected onto the plane
- Magnetic field wraps around the cavity



Faraday Rotation

Small scale structure

Dickey & Lockman Atmosphere. $B = \text{const}$ $\beta = 1$ $t = 10 \text{ Myr}$



Summary

- Bubbles evolve differently depending on magnetic fields present
- Axial ratio in the plane of the Galaxy is independent of magnetic configuration and atmosphere
- Fitting Kompaneets to a magnetized bubble with line of sight along field lines results in smaller scale height
- Rotation Measure maps can reveal the magnetic or density structure of the medium surrounding a superbubble

Work in Progress

- Effect of cooling on morphology of magnetized and non magnetized bubbles